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SPEED CONTROL OF A 6/4 SWITCHED RELUCTANCE MOTOR DRIVE

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ABSTRACT

Now a days, Switched Reluctance Motors (SRMs) attract more and more attention. The Switched Reluctance Motor is simple to construct. It not only features a salient pole stator with concentrated coils, which allows earlier winding and shorter end returns than other types of motors, bur also features a salient pole rotor, which has no conductors or magnets and is thus the simplest of all electric machine rotors. Simply makes the SRM inexpensive and reliable, and together with its high speed capacity and high torque to inertia ratio, makes it a superior choice in different applications. The open loop and closed loop control of SRM drive is presented in this paper. Finally open loop and closed loop controllers for a three phase 4/6 SRM drive is implemented in Matlab/simulink software and the corresponding results are presented.

KEYWORDS: Switched Reluctance Motor Drives, Converter Topology

INTRODUCTION

At an age of more than 150 years, and counting, the switched reluctance motor (SRM) represents one of the oldest electric motor designs around. Partly as a result of recent demand for variable-speed drives and primarily as a result of the development of power semiconductors, a variation on the conventional reluctance machine has been developed and is known as the “switched reluctance" (SR) machine. The name “switched reluctance", first used by one of the authors of [1], describes the two features of the machine configuration: (a). switched -the machine must be operated in a continuous switching mode, which is the main reason the machine developed only after good power semiconductors became available; (b). reluctance - it is the

True reluctance machine in the sense that both rotor and stator have variable reluctance magnetic circuits, or, more properly, it is a double salient machine. The concept of the switched reluctance machine is actually very old, going back to the 19th century inventions called “electromagnetic engines" [2], which were the forerunners of modern stepper motors. The switched reluctance motor is basically a stepper motor and has had many applications as both rotary and linear steppers. The idea of using the SR configuration in a continuous mode (on contrast to a stepper mode) with power semiconductor control is due primarily to Nasar [1], French [3], Koch [4] and Lawrenson [5] in the 1960's. At that time, only thyristor power semiconductors were available for the relatively high-current, high-voltage type of control needed for SR machines. These years, power transistors, GTOs, IGBTs, and power MOSFETs have been developed in the power ranges required for SRM control. Simple construction is a prime feature. SR motors eliminate permanent magnet (PMs), brushes and commutators. The stator consists of steel laminations forming salient poles [6-7]. A series of coil windings, independently connected in phase pairs, envelops the stator poles. With no rotor winding, the rotor is basically a piece of steel (and laminations) shaped to form salient poles. It is the only motor type with salient poles in both the rotor and stator (double salient). As a result, and also because of its inherent simplicity, the SR machine promises a reliable and low-cost variable-speed drive and will undoubtedly take the place of many drives now using the cage induction and DC commutator

machines in the short future. The torque ripple and noise as a result of this commutation are the other two awkward issues which have to be tackled. All these make the control of the SRM a tough challenging. This paper presents a new Converter topology for speed control of SRM drive. In order to get the good transient response, the overall proposed system is implemented in closed loop configuration.

PRINCIPLE OPERATION OF SRM

Switched Reluctance Motor has wound field coils of a dc motor for its stator windings and has no coils or magnets on its rotor. Both the stator and rotor have salient poles, hence the machine is referred to as a doubly salient machine. Switched Reluctance Motors are made up of laminated stator and rotor cores with Ns=2mq poles on the Stator and Nr poles on the rotor. The number of phases is m and each phase is made up of concentrated coils place on 2q stator poles. Most favored configuration amongst many options are 6/4 three phase and 8/6 four phase Switched Reluctance Motors's as shown in the figure 1. These two configurations correspond to q = 1(one pair of stator poles and coils per phase) but q may be equal to 2 or 3 also. With only one phase switched on; the rotor will be at rest in a position which provides minimum reluctance for the flux produced by that phase. In this position, there will not be any developed torque on the rotor. Now if that phase is switched off and another phase switched on; the rotor experiences a torque tending to move it to a minimum reluctance position corresponding to the new phase. Whichever direction of movement offers the least distance to be moved by the rotor to reach the new minimum reluctance position is the direction of rotor motion. Singly excited electromagnetic relays have been analyzed using the principles of electromechanical energy conversion Expressions for electromagnetic torque have been developed. These results can be extended to the switched reluctance motor, and the expression for the torque is obtained as

$$T_e = \frac{dL(\theta,i)}{d\theta}\frac{i^2}{2} \tag{1}$$

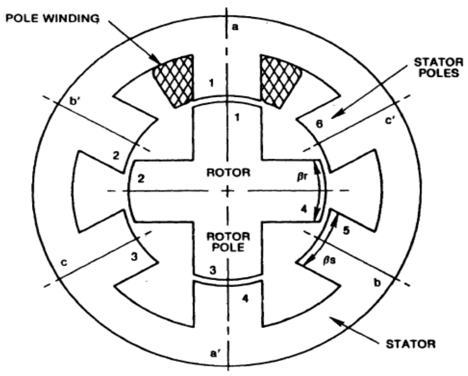

Figure 1: Basic Three Phase 6/4 SRM

CONVERTER TOPOLOGY AND SPEED CONTROL OF SRM

The SR drive has additional advantages compared with the conventional adjustable-speed ac or brushless dc drives (including permanent-magnet motor drives). First, shoot through faults are impossible. This is true for all SR converter circuits because there is always a motor winding in series with each main power switching device. Second, there is a greater degree of independence between the phases than is possible in conventional ac or brushless dc drives. A fault in one phase (whether in the motor or in the converter) generally affects only that phase; the other phases can continue to operate independently. Among those converters, the asymmetric bridge converter is the most popular and best-performed one, in which each phase branch consists of two discrete switching components and two freewheeling diodes, as shown in Figure 2.

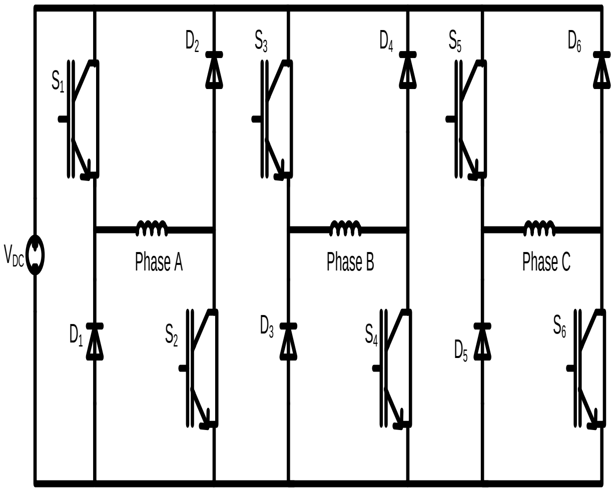

Figure 2: Asymmetrical Bridge Converter for Three Phase 6/4 Pole SRM

When switches S1 and S2 are turned ON, the phase A is energized which is shown in figure 3.

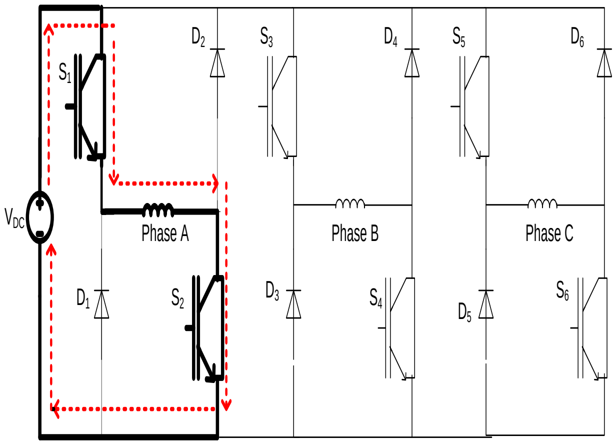

Figure 3: Current Path when Phase a is Energized

When switches S1 and S2 are turned OFF, the diodes D1 and D2 are forward biased. In this case phase A is denergized, which is shown in figure 4.

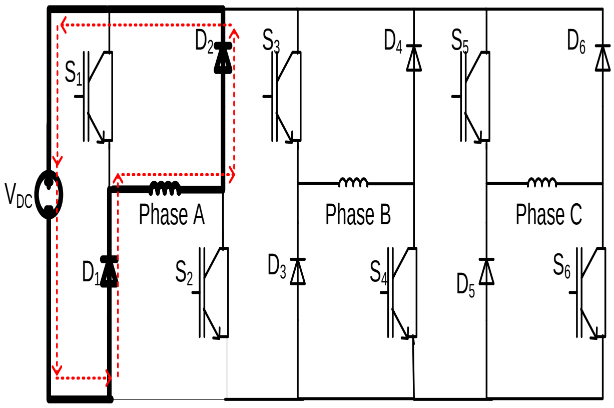

Figure 4: Current Path when Phase a is Denergized

For getting fast transient response, the overall drive system is implemented in closed fashion, which is shown in the figure 5.

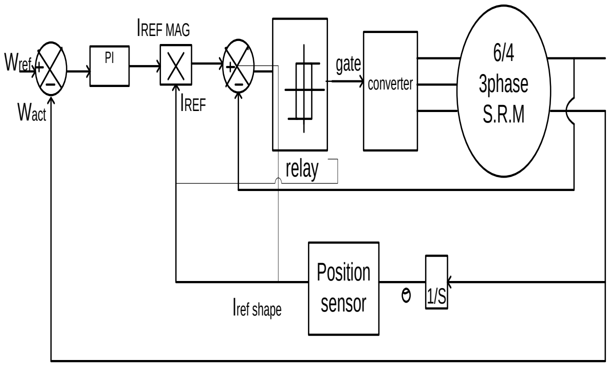

Figure 5: Closed Loop Control of SRM Drive System

The above figure shows the closed loop control implementation of SRM drive system. The actual speed of the motor is compared with the reference speed give the speed error.

The speed error is applied to PI controller generates the reference current which generates the required gate pulses for driving the motor.

MATLAB/SIMULINK MODELLING AND SIMULATION RESULTS

Case (1): *SRM drive with open loop control*

The following figure 6 shows the Matlab/simulink diagrm of open control of SRM drive system.

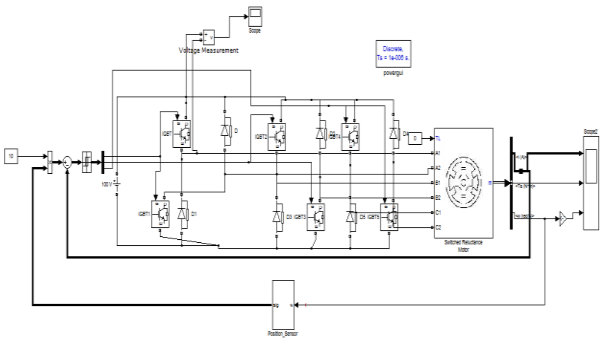

Figure 6: Matlab/Simulink Diagrm of Open Control of SRM Drive System

The following figure 7 shows the current, electromagnetic torque and speed of SRM drive system.

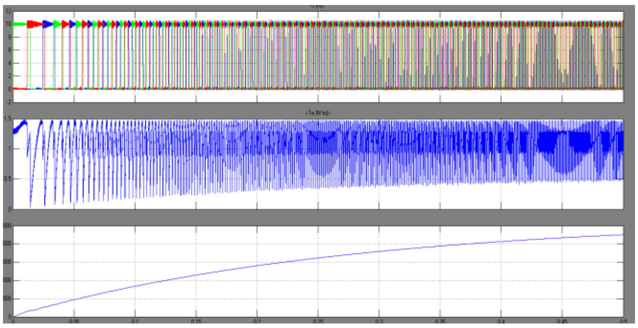

Figure 7: Current, Torque and Speed of SRM Drive System

Case (2): *SRM drive with closed loop control*

The following figure 8 shows the Matlab/simulink diagrm of closed control of SRM drive system.

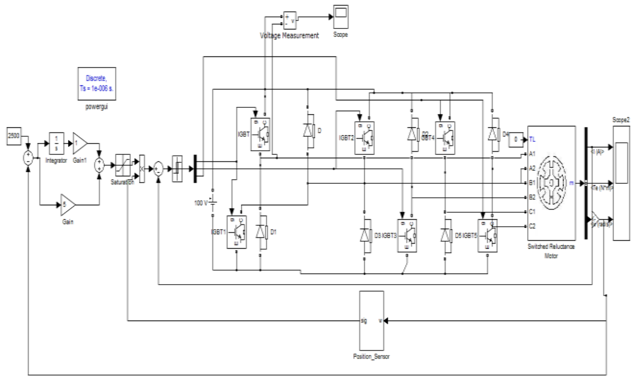

Figure 8: Matlab/Simulink Diagrm of Closed Loop Control of SRM Drive System

- *With kp= 5, Ki = 1*

The following figure 9 shows the current, electromagnetic torque and speed of SRM drive system.

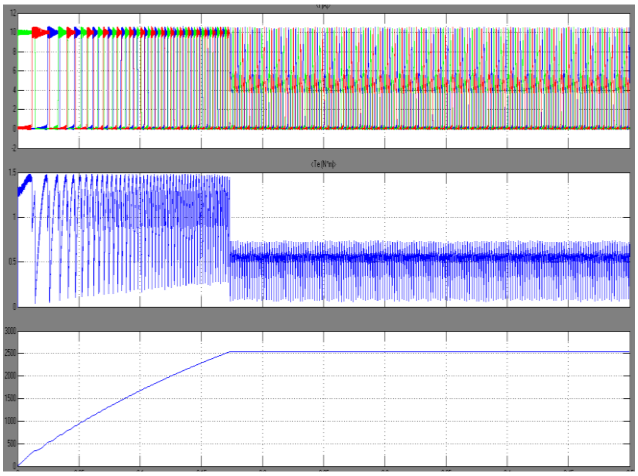

Figure 9: Current, Torque and Speed of SRM Drive System in Closed Loop Control Scheme with kp= 5, Ki = 1

- *With kp= 0.5, Ki = 0.1*

The following figure 10 shows the current, electromagnetic torque and speed of SRM drive system.

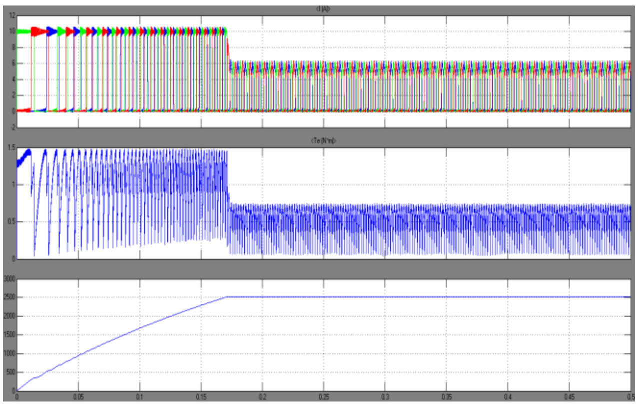

Figure 10: Current, Torque and Speed of SRM Drive System in Closed Loop Control Scheme with Kp= 0.5, Ki = 0.1

- *With kp= 0.1, Ki = 0.01*

The following figure 11 shows the current, electromagnetic torque and speed of SRM drive system.

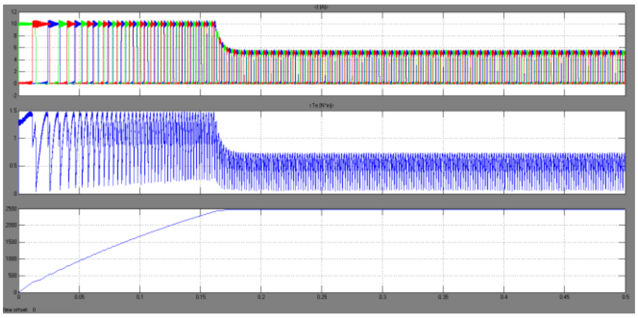

Figure 11: Current, Torque and Speed of SRM Drive System in Closed Loop Control Scheme with Kp= 0.1, Ki = 0.01

The following table 1 show the rise time and % error of the SRM drives for different Kp and Ki values.

Table 1: Rise Time and % Error of Speed Different Kp & Ki Values

	Kp=5, ki= 1	Kp=0.5, ki= 0.1	Kp=0.1, ki= 0.01
Rise Time For Motor Speed	0.1731s	0.171s	0.165s
% Error In Motor Speed	0.014	0.01	0.0124

From the above table, the drive system with closed loop PI controller parameters Kp=0.1, ki= 0.01 reaches steady state quickly compared to other PI controllers with different Kp and Ki values, because the rise time for this controller is less as compared to others.

CONCLUSIONS

This paper presents the open loop and closed loop control of three phase 4/6 pole switched reluctance motor (SRM) drive. A new asymmetrical bridges converter topology is implemented for the drive system. Closed loop control using PI controller with different Kp and Ki values are presented in this paper. Closed loop and open loop controller for SRM drive is implemented in Matlab/Simulink environment. From the simulation results, PI controller with Kp=0.1 and Ki=0.01 gives the better performance in terms of rise time.

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